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Fire Retardant-Caused Corrosion—A 1986 Field Reassessment

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THE AUTHORS

CHARLES W. GEORGE received his B.S. degree in forest engineering in 1964 and M.S. degree in forestry in 1969. He joined Intermountain Station's staff in 1965 where he has conducted studies related to prescribed fire, pyrolysis and combustion, fire retardants, and aerial delivery systems. Presently Mr. George is project leader of the Fire Suppression research work unit at the Intermountain Fire Sciences Laboratory (formerly Northern Forest Fire Laboratory). The current mission of the work unit is to develop the knowledge and application systems needed to improve fire control capabilities, to reduce costs, and to improve chemical fire suppression technology.

GEORGE A. GEHRING, JR., graduated from Drexel University in 1966 with a degree in electrical engineering. Mr. Gehring received his M.S. degree from Drexel University in metallurgical engineering in 1969. He is an accredited corrosion specialist by the National Association of Corrosion Engineers. He joined A. V. Smith Engineering Co. in 1969; he became staff engineer for A. V. Smith Engineering Co./ Ocean City Research Corp. In 1973 he was appointed a vice president, in addition to principal investigator for research conducted by Ocean City Research Corp., Ocean City, NJ. He has been involved in field surveys of chemical firefighting equipment and operations and has conducted retardant corrosion research for the Forest Service and cooperators.

RESEARCH SUMMARY

The corrosivity of long-term wildland fire retardants delivered by airtankers has been a continuing concern since the beginning of the retardant program in 1955. During the fall of 1986, the severity of corrosion was investigated at air-attack bases in Oregon, California, and Nevada. At the 10 air bases visited, 25 different airtankers were inspected, and personnel from the bases and the contract airtanker operators were interviewed. The survey established that fire retardant corrosion of airtankers continues but the problem is not getting worse. It is recommended that wildland fire management agencies responsible for aerial fire retardant operations maintain a program to monitor the corrosivity of its approved fire retardants and corrosion problems related to their use.

Cover photo: Corrosivity of forest fire retardants, as evidenced by the color photo of an aircraft tank and gating system in the drop position, remains a serious problem among retardant bases surveyed in this report.

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INTRODUCTION

Over the past 15 years the USDA Forest Service has expended considerable effort toward reducing fire retardant-caused corrosion of airtankers used to deliver fire retardant and the equipment used to mix, store, and handle it. This effort has reduced costly equipment and hardware failures, extended the life of equipment, reduced maintenance costs, and reduced the risk of aircraft failures. Many of the corrosion control initiatives implemented by the Forest Service and other fire management agencies resulted from field surveys and laboratory studies conducted between 1973 and 1978. Because of recent changes in the chemical formulations of retardants, in 1986 the Forest Service decided to reassess the situation. As a result, the Ocean City Research Corporation was contracted to participate in a field survey of fire retardant bases in Oregon, California, and Nevada. The objectives of the survey were to: (1) assess the extent to which corrosion still persists, (2) determine whether changes in chemical formulations and equipment have affected corrosion problems, and (3) evaluate the effectiveness of initiatives implemented during the past 10 years. This report describes results of the 1986 field survey.

FOREST SERVICE CORROSION STUDIES

Corrosion of airtankers and retardant storage and mixing equipment has been considered a problem since the very beginning of the retardant program (Operation Firestop, 1955). In 1964, the Arcadia Equipment Development and Test Center (Forest Service) tested retardant formulations not containing corrosion inhibitors on several metals commonly used in airtankers (see fig. 1). The results showed that the retardants were corrosive in varying degrees, from failures within 2 days to only small pits after a year's time, depending on the retardant-metal combinations examined.

After the 1964 fire season, inspection of airtankers used to carry several different retardants revealed varying amounts of corrosion damage (see fig. 2). The degree of damage was found to be related to the type of retardant, the type of metal used in construction of the aircraft and tanks, the use of protective coatings, and the housekeeping practices of the operators. These examinations resulted in recommendations for reducing corrosion to aircraft and equipment.

Figure 1—Pitting corrosion of aluminum tank gate.

Figure 2—Corrosion of steel end fitting on Aeroquip hydraulic hoses.

Figure 3—Failure of stranded steel cable.

Early in 1968, the San Dimas Equipment Development Center (Forest Service) conducted a variety of corrosion tests using different retardants. In 1969-70, partially as a result of this testing, the Forest Service included permissible corrosion rates in specifications for both dry and liquid retardants (interim specifications 5100-00301 and 5100-00302a).

In 1973, in an effort to obtain better insight into corrosion and appropriate methods for its control, Ocean City Research Corporation was contracted to: (1) assess the corrosive effects of retardant on mixing and delivery systems, particularly airtankers; (2) determine the corrosion rates on alloys that make up commonly exposed and

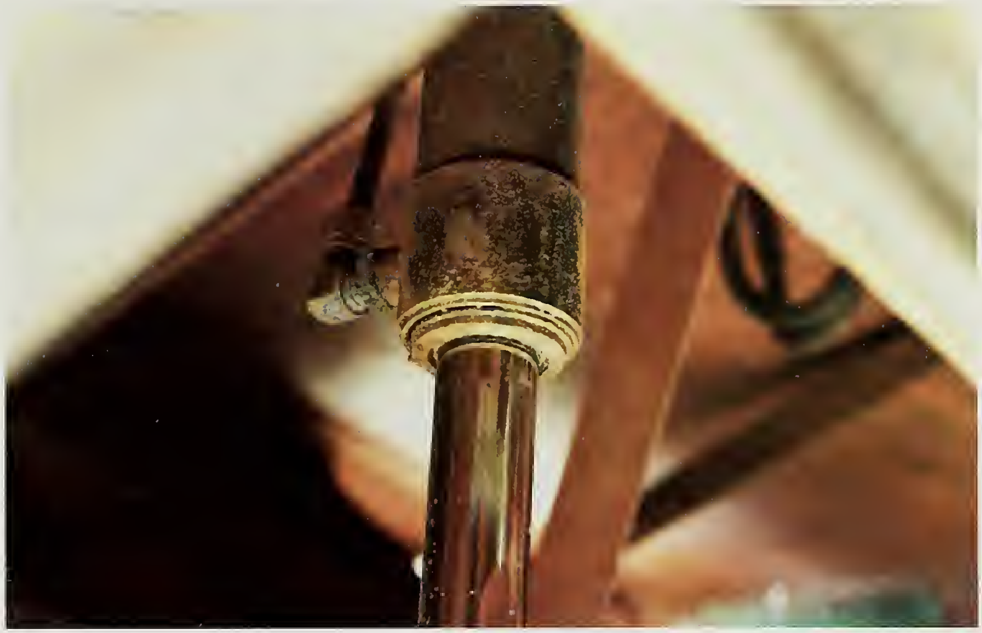

Figure 4—Corrosion of steel hydraulic piston barrel.

Figure 5—Corroded aluminum structural stiffener from DC-6 tail cone.

critical parts; (3) correlate these rates to actual operational damage; and (4) recommend methods for reducing corrosion.

Between 1973 and 1980, Ocean City Research Corporation conducted a comprehensive investigation of corrosion, including numerous field inspections and extensive laboratory studies. These studies resulted in three separate technical reports (see figs. 3, 4, 5). In addition, the Intermountain Fire Sciences Laboratory initiated in-house studies that have continued to the present.

THE 1986 FIELD SURVEY

Survey Team

A six-person team of fire management, equipment, and research specialists from the Forest Service, California Department of Forestry, and Ocean City Research Corporation was assembled to survey airtankers and air attack bases in Oregon, California, and Nevada in September 1986. The members of the team were:

Skip Alderson, Forest Service, Pacific Northwest Region, Fire and Aviation Management

Al Cadola, Forest Service, Pacific Northwest Region, Fire and Aviation Management

Dave Day, State of California, Department of Forestry and Fire Protection

George Gehring, Ocean City Research Corporation

Charles George, Forest Service, Intermountain Research Station

Paul Hill, Forest Service, San Dimas Technology and Development Center

Air Attack Bases and Airtanker Operators Included in Survey

During the survey, 10 air attack bases and five airtanker contractors were visited. The location of the bases, the contractors visited, and the type of retardant being used at each base at the time of the survey are identified in appendix A.

Airtankers Included in the Survey

A total of 25 airtankers were inspected during the survey. Appendix B shows the airtankers inspected, estimated time in service as an airtanker, and type of retardant primarily or recently used (as stated by the operator, aircraft pilot, or maintenance crew). The distribution of aircraft inspected according to model was as follows:

DC-4	2	S-2	7
DC-6	8	P2V	1
DC-7	4	C119	2
C-123	1		

These aircraft averaged 10.2 years service as airtankers (appendix B).

RESULTS AND DISCUSSION

Airtankers

Corrosion problems identified during the survey were either (1) observed on operational equipment or (2) observed on components that had been removed and replaced during maintenance or repair of airtankers or mixing, storage, or transfer equipment. A total of 23 separate corrosion problems were identified and are briefly described in appendix C. Of these, several are similar. Also, several of the problems are generic to a specific type of aircraft or tank and gating system. A review of the 23 corrosion problems revealed 11 basically different corrosion problems and these are illustrated in figures 6-15, as follows:

1. Pitting corrosion of aluminum tank gates and solenoids (figs. 1, 7, and 11)

Figure 6—Corrosion of aluminum tail skid.

2. Corrosion of steel end fittings on Aeroquip hydraulic hoses (fig. 2)

3. Corrosion of stranded steel cabling (figs. 3 and 8)

4. Corrosion of steel hydraulic piston barrels and seals (figs. 4 and 12)

5. Internal corrosion of aluminum DC-6 tail cones (fig. 5)

6. Corrosion of aluminum tail skids (fig. 6)

7. Corrosion of steel rear wheel retraction pistons and cylinder pins on S-2's (figs. 9 and 10)

8. Corrosion of steel fastener hardware (figs. 13a and b)

9. Corrosion of aluminum torque arms (figs. 14a and b)

10. Corrosion of steel S-2 rear wheels and bearing races (fig. 15)

11. Corrosion of steel tank door hinges (not shown).

Figure 7—Corroded tank gate solenoid.

Figure 8—Broken stranded steel cable between tank equalizer flaps.

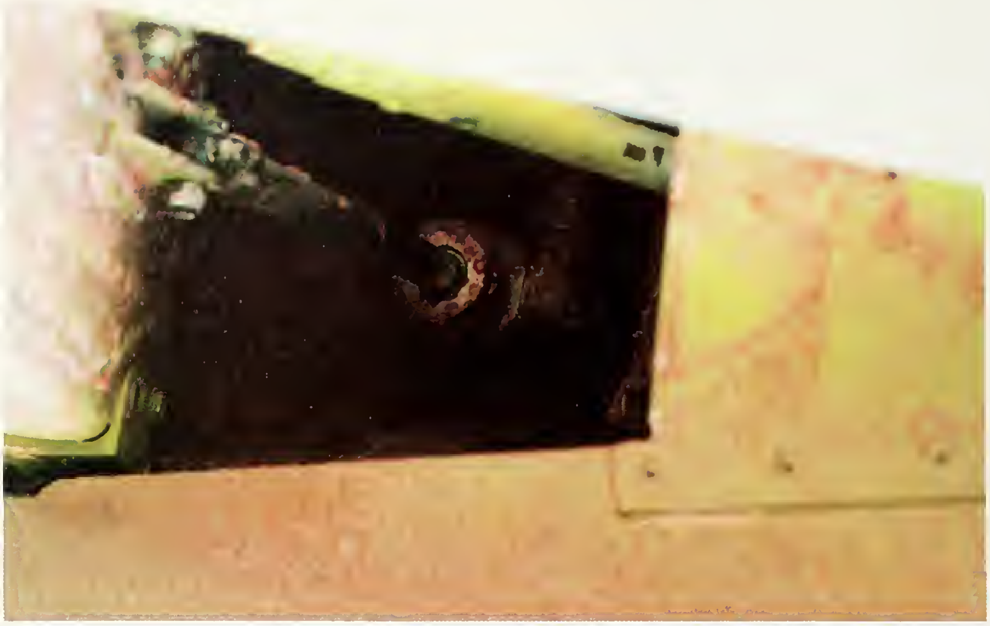

Figure 9—Corrosion of attached rear wheel retraction piston.

Figure 10—Corroded rear wheel retraction piston.

Figure 11—Pitting of aluminum tank gate.

Figure 12—Corrosion of piston seal.

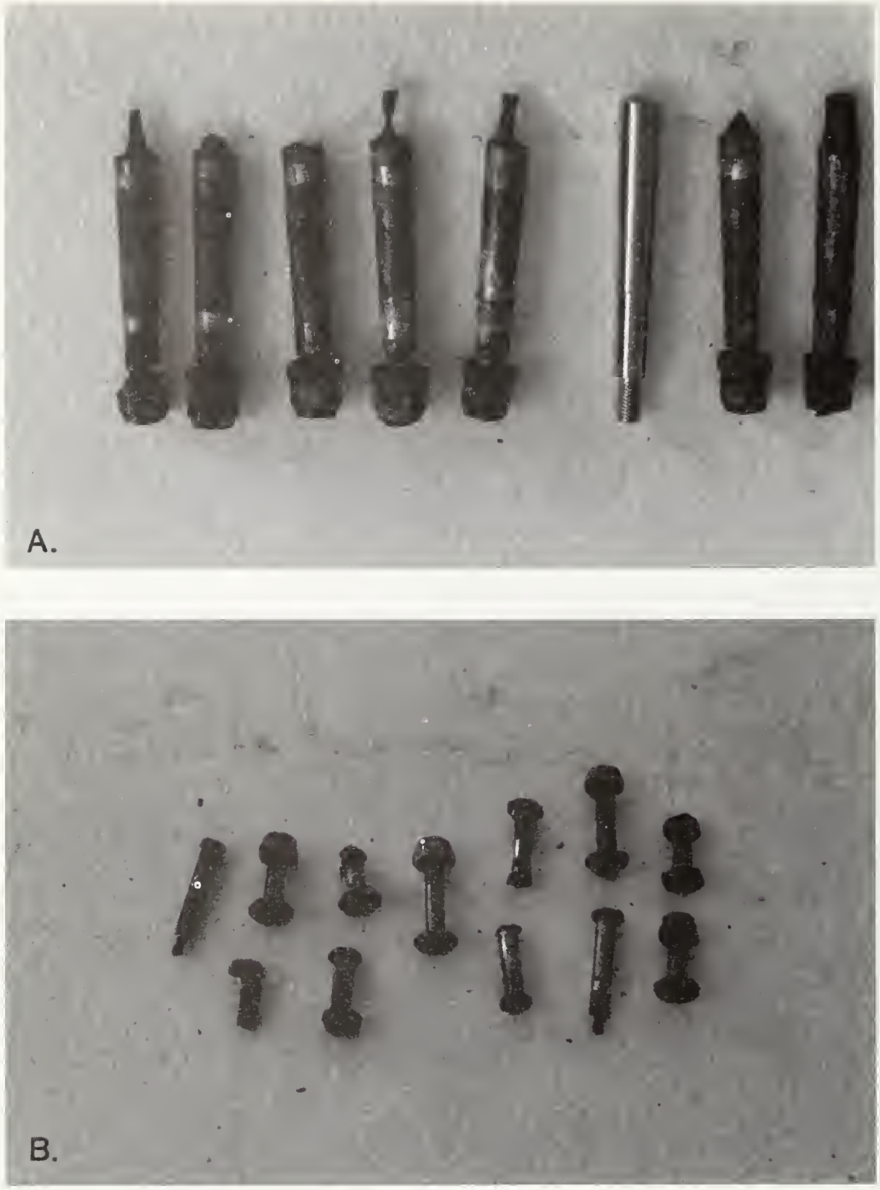

Figure 13—Corroded steel fasteners: (A) steel torque tube taper pins, (B) miscellaneous steel fasteners used in door opening assembly.

Figure 14—Corroded aluminum torque arm: (A) general view, (B) pitting at attach point.

Figure 15—Corroded rear wheel removed from an S-2.

As in past field surveys, it was obvious that a wide difference of opinion exists among the people associated with airtanker operations on almost every issue related to fire retardant-caused corrosion. This includes the nature and cause of the various corrosion problems, the seriousness of the problems, and the priority for solving various problems. This diversity of opinion makes it difficult to compare the degree and extent of corrosion with what it was 10 years ago.

Some of the aircraft had seen long service having many different retardants. But because the quantities of various formulations and history of exposure had not been recorded, it was nearly impossible to correlate damage with the use of a specific retardant. Thus, it is difficult to evaluate opinions about the relative corrosivity of the different retardants. It is indisputable that corrosion problems still continue, but opinions as to their seriousness vary widely.

Many of those interviewed contended that the new formulations (Fire-Trol GTS, Phos-Chek D75) are causing corrosion problems not observed previously. Specifically noted were accelerated corrosion of exposed steel fastener hardware and steel hydraulic components in tanks and corrosion of aluminum torque arms. Given the observations of the survey team and the frequency of the complaint concerning corrosion of steel hardware exposed in tanks, it would seem that attention should be given to this particular problem. The reported rate of corrosion attack (for instance, severe necking of bolts in one fire season) appears to be much greater than would be expected from approved retardants. The Forest Service fire retardant specification requires that approved retardants corrode 4130 steel at less than 5.0 mils per year (mpy) under specified partial immersion conditions. The reported attack is far in excess of this rate. Given the small area of steel as compared to aluminum in a typical tank, the problem suggests the presence of galvanic corrosion. Based on previous laboratory studies, steel was ordinarily electrochemically less active than aluminum and, thus, would not be expected to galvanically corrode when coupled to aluminum. But there were exceptions—specifically, in Fire-Trol 100, an ammonium sulfate-type retardant. (Both new formulations, Fire-Trol GTS and Phos-Chek D75 are ammonium sulfate-based retardants.) Thus, there is a need to investigate the propensity for galvanic corrosion between steel and aluminum in the new retardant formulations.

Some of the above problems can be solved without modifying the chemical corrosivity of the approved retardants. For example, corrosion of steel fastener hardware in aircraft tanks was mitigated in several airtankers by the judicious use of protective coatings/sealants or the substitution of stainless steel. At a certain point further modification of the retardant formulations to reduce corrosivity will prove less cost effective than other measures (for example, use of protective coatings, substitution of more resistant alloys). Some of those measures have been described in the recent publication "Guidelines for Preventing Fire Retardant Corrosion" (fig. 6).

Mixing Plants

Corrosion of mixing plants is far less of a problem than it was 10 years ago. This is partly due to new designs in

retardant mixing systems. Also, the replacement of Fire-Trol 100, known to be highly corrosive to steel, with Fire-Trol 931L, LCA, and more recently Fire-Trol GTS, all meeting the more restrictive uniform corrosion requirements (especially partial corrosion of steel) has reduced corrosion commonly observed on steel. Finally, mixing plant operators are now more knowledgeable about corrosion and prevention methods.

There were a few exceptions to the general findings at mixing plants. Accelerated corrosion penetration of steel storage tanks was reported at a few plants (Santa Rosa, Chico). The corrosion (pitting tendency) was associated with Phos-Chek A (a monoammonium phosphate-based retardant), which has since been replaced and is no longer available. Laboratory studies and consultation with experts suggested that the corrosion was biologically induced. Future reports of such damage should be monitored by fire management agencies to determine whether this type of corrosion remains a problem.

Other Problems

Related problems noted during the survey include cracking of the rubber hydraulic hoses in the tanks and disbondment/peeling of certain protective paints and sealants applied to tanks (both airtankers and mixing plants). The tanks of several aircraft had been coated with epoxy. Inspection showed that this type of coating is effective for protecting both the tank and its internal parts.

CONCLUSIONS

1. Airtankers and mixing plants continue to suffer corrosion from fire retardants. Assessment of present-day severity versus that of 10 years ago is difficult. Field personnel differ on this point, and lack of documentation makes it difficult to correlate observed damage to the use of specific retardants. There is no overwhelming evidence that corrosion has grown significantly worse, although in several instances (with respect to exposure to steel and aluminum) corrosion damage was greater than expected.
2. The current rate of corrosion to airtankers and mixing plants is severe enough to warrant further research into its causes and how to mitigate it, and a continued program of periodic inspections.
3. New formulations may have increased the propensity for steel to corrode when coupled to aluminum.
4. Application of existing guidelines for preventing fire retardant-caused corrosion can be effective.

RECOMMENDATIONS

1. The Forest Service should maintain a program to continually assess the corrosivity of approved retardants and corrosion problems related to their use. This should include assessment of the permissible rates of corrosion (methods and procedures, alloys, type of corrosion, exposures, etc.).
2. New retardant formulations (Fire-Trol GTS, Phos-Chek D75) should be studied to determine effect on galvanic corrosion between steel and aluminum.
3. Implementation of Forest Service guidelines for preventing or minimizing fire retardant-caused corrosion should receive maximum emphasis.

REFERENCES

David, J. B.; Phillips, C. B. 1965. Corrosion of airtankers by fire retardants. A report for California Air Attack Coordinating Committee. Sacramento, CA: California State Division of Forestry. 38 p.

Gehring, G. A., Jr. 1974. An investigation of fire retardant caused corrosion. A report on contract 26-3250 to: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT. 121 p.

Gehring, G. A., Jr. 1978. Laboratory studies of fire retardant corrosion. A report on contract 26-3250 to: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT. 55 p.

Gehring, G. A., Jr. 1980. An investigation of fire retardant caused corrosion (extended study). A report on contract 40-0353-7-799 to: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT. 56 p.

Gehring, G. A., Jr.; George, C. W. 1986. Guidelines for preventing fire retardant corrosion. Gen. Tech. Rep. INT-210. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 22 p.

U.S. Department of Agriculture, Forest Service. 1964. Corrosion to airtankers from fire retardant chemicals. Equip-Tips. Arcadia, CA: U.S. Department of Agriculture, Forest Service, Arcadia Equipment Development Center.

U.S. Department of Agriculture, Forest Service. Long term retardant specifications for aircraft or ground application. Interim specification 5100-00304. Washington, DC.

APPENDIX A: AIR ATTACK BASES AND CONTRACTORS INCLUDED IN SURVEY

Air Attack Bases

Location	Type of Fire Retardant[1]
Chico, CA	Phos-Chek D75
Fresno, CA	Phos-Chek D75
Hollister, CA	Fire-Trol GTS
Klamath Falls, OR	Fire-Trol LCA
Medford, OR	Fire-Trol GTS
Minden, NV	Fire-Trol 100
Redding, CA	Fire-Trol GTS
Redmond, OR	Fire-Trol GTS
Santa Rosa, CA	Phos-Chek D75
Stockton, CA	Phos-Chek D75

Airtanker Operators[2]

Firm	Location
Aero Union Corporation	Chico, CA
Butler Aviation	Redmond, OR
Hemet Valley Aviation	Stockton, CA
Macavia International	Santa Rosa, CA
TBM Incorporated	Tulare, CA

[1]Retardant being used at the time the survey was conducted (September 1986).

[2]Airtanker operators surveyed included owner/operators in addition to those visited (see appendix B).

APPENDIX B: AIRTANKERS INCLUDED IN SURVEY

Type	Identification[1] Airtanker	No.	Owner	Location	Estimated years service	Comments on retardant use[2]
DC-4	N111712	02	Aero Union	Fresno	10	PC-D75 recently
DC-4	N2742G	15	Aero Union	Fresno	3	PC-D75 recently
DC-4	N42185	18	Aero Union	Redding	3	FT 100, GTS 1986, all retardants previously
DC-6	N90MA	21	Macavia	Sonoma	12	Mostly FT 931, PC-D75 (1986) FT (1985)
DC-6	N444SO	44	Macavia	Medford	11	FT-GTS 1986, FT 931 previous season
DC-6	N555SO	45	Macavia	Klamath Falls	15	FT 931, FT-GTS, PC-D75 recently
DC-6	N111AN	46	Macavia	Sonoma	14	Mostly FT 931 in recent years, some GTS in 1985
DC-6	N666SO	47	Macavia	Chico	15	PC-D75 1985, all previously
DC-7	N838D	60	TBM	Fresno	10	FT-GTS, PC-D75 recently
DC-7	N848	61	TBM	Fresno	6	PC-D75 recently
C-123	N3142D	63	TBM	Fresno	3	PC-D75 (2 years)
DC-7	N6353C	66	Butler	Redmond	10	All retardants
DC-7	N6318C	67	Butler	Redmond	12	FT-GTS 1986, FT 931 previous season
S-2	N412DF	72	CDF	Chico	11	All retardants except FT 931
S-2	N406DF	73	CDF	Redding	14	FT-GTS 1986, PC-D75 previous season
C-119	N13743	81	Hemet Valley	Minden	9	PC-D75, FT 100, FT 931
C-119	N13744	86	Hemet Valley	Redding	20	FT-GTS last 2 years
S-2	N450DF	90	CDF	Sonoma	12	Mostly PC-D75 last few years
S-2	N453DF	91	CDF	Sonoma	12	Mostly PC-D75 last few years
S-2	N452DF	92	CDF	Sonoma	12	Mostly PC
S-2	447DF	93	CDF	Hollister	12	FT-GTS last 2 years
DC-6	N90739	97	TBM	Minden	11	PC-D75, FT-GTS, FT 100, FT 931
S-2	N436DF	100	CDF	Fresno	8	PC-D75 recently
P2V	N202EV	141	Evergreen	Chico	8	FT 931 (1986)
DC-4	N90203	166	Hemet Valley	Sonoma	3	PC-D75 (1986), FT 931 (1986)

[1]The airtanker number is that number assigned by the Interagency Airtanker Board and displayed on the tail of all airtankers.

[2]History of exposure of airtankers to specific retardants is difficult to define since airtankers carry most all retardant types and are moved to different bases throughout the season. Comments by pilots or operators about primary exposure the last few seasons are noted.

APPENDIX C: CORROSION PROBLEMS NOTED DURING SURVEY

No.	Problem	Description	Source	Ref. fig.	Other remarks
1	Pitting corrosion of aluminum tank gates.	Deep pits (up to 1/8-inch) observed on tank gating (believed to be 7075 Al).	DC-6 (N444SO) T44	1	Pilot believes attack in tank gates occurred this season hauling FT-GTS.
2	Corrosion of steel end fittings on Aeroquip hydraulic hoses.	Rusting and general surface corrosion observed on end fittings.	DC-6 (N444SO) T44	2	
3	Failure of stranded steel cable between tank equalizer flaps.	Cable exhibits significant corrosion of strands—indicating corrosion contributed to failure.	S-2 (N406DF) T73	3	
4	Corrosion of steel hydraulic piston barrels.	General surface corrosion and pitting of steel piston barrels on tank gating hydraulics.	DC-6 (N90MA) T21	4	Mechanic reports that this has been a common problem—piston barrels have been overhauled and painted on some aircraft.
5	Corrosion of steel end fittings on Aeroquip hydraulic hoses.	Same as 2.	DC-6 (N90MA) T21	4	Mechanic also reports this to be a common problem.
6	Corrosion of steel fastener hardware in tanks.	General surface rusting and pitting of tank fasteners.	Reported by aircraft mechanic at Sonoma.	—	Mechanic advises that all fastener hardware now coated with 3M EC800 (rubber sealant).
7	Internal corrosion of tail cone on DC-6's.	General surface corrosion of aluminum stiffeners and fuselage in the tail cone.	Reported by aircraft mechanic at Sonoma—corroded parts inspected in maintenance shop.	5	Mechanic advises that retardant seeps through access plate in the tail cone, builds up, and causes corrosion.
8	Corrosion of cast aluminum tail skid.	Extensive corrosion and deep pitting (including penetration observed on cast aluminum tail skid).	DC-4 (N90203) T166	6	
9	Corrosion of tank gate solenoids and attaching hardware.	Corrosion of tank gate solenoids and attaching bolts observed underneath front and rear fairings.	DC-4 (N90203) T166	7	
10	Broken cable between tank equalizer flaps.	Corrosion observed on broken stranded steel cable—appears to have contributed to failure.	S-2 (N452DF)	8	
11	Corrosion of rear wheel retraction piston.	Surface corrosion observed on rear wheel retraction piston.	S-2 (N436DF) T100	9	
12	Corrosion pitting on tail skid.	Pitting observed on tail skid.	DC-4 (N11712) T02		
13	Corrosion pitting on tail skid.	Same as 12.	DC-4 (N2742G) T15	—	

(con.)

APPENDIX C (Con.)

No.	Problem	Description	Source	Ref. fig.	Other remarks
14	Corrosion failure of tank door hinges.	Hinge suffered extensive corrosion.	Reported by aircraft mechanic at Klamath Falls.	—	Lost two doors when dropping load; all doors and hinges to be overhauled during winter.
15	Corrosion of rear wheel retraction piston.	Same as 11.	Reported by aircraft mechanic at Hollister.	10	Mechanic advised retardant enters breather hole in piston and corrodes internals.
16	Pitting of tank gates.	Deep pitting observed beneath blue film formed on tank door.	DC-6 (N555SQ) T45	11	Pitting attack on gate varies significantly depending on location.
17	Corrosion of piston seals.	Significant corrosion observed on piston seals on tank gate hydraulic system.	DC-6 (N555SQ)	12	Aircraft mechanic advises that replacement of piston seals due to corrosion is a continual problem.
18	Corrosion of steel fastener hardware.	Severe corrosion (necking of bolts) reportedly occurred on fastener hardware used to hold tank in aircraft. Corrosion also noted on torque tube pins.	Reported by representatives of contract airtanker operator.	13a,b	Representatives of contract airtanker operator advise corrosion occurred in one fire season using FT-GTS.
19	Corrosion of torque arms.	Corrosion attack (pitting) observed on aluminum (Tenzaloy) torque arms.	Reported by representatives of contract airtanker operator.	14a,b	Representatives of contract airtanker operator advise corrosion occurred in one fire season (3 mos) in PC-D75 with aircraft sitting loaded.
20	Corrosion of steel bolt heads.	Corrosion attack reported on bolt heads in several tanks.	Reported by representatives of contract airtanker operator.	—	Reported as problem occurring only in recent years.
21	Corrosion of rear wheel retraction piston.	Same as 11.	Reported by representatives of contract airtanker operator	—	Airtanker operator advised continued problem on S-2 rear wheels; rear piston had to be replaced after 118 hours because of corroded cylinder seal.
22	Corrosion of rear wheels.	Surface corrosion of rear wheel bearing races.	Reported by representatives of contract airtanker operator	15	Airtanker operator advised rear wheels have to be replaced every 1-2 years because of corrosion of bearing races.
23	Corrosion of steel fastener hardware.	Steel bolts reportedly severely necked down after 5 years on S-2 (tanker #70).	Reported by representatives of contract airtanker operator.	—	Airtanker stationed at Sonoma and carried mostly PC.

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In 1986, selected air attack bases in the Western United States were inspected to reassess the threat of fire retardant-caused corrosion to aircraft and retardant-mixing equipment. Conclusions were that the corrosion problems had not worsened during the previous 10 years but remained serious enough to warrant continued monitoring, additional emphasis on prevention guidelines, and further research—particularly into the possibility that new retardant formulations are accelerating galvanic corrosion where aluminum joins steel.

KEYWORDS: alloys, mixing plants, guidelines, coatings, maintenance, survey, wildland fires, aircraft corrosion, chemical retardants, corrosion prevention, galvanic corrosion, retardant specifications

INTERMOUNTAIN RESEARCH STATION

The Intermountain Research Station provides scientific knowledge and technology to improve management, protection, and use of the forests and rangelands of the Intermountain West. Research is designed to meet the needs of National Forest managers, Federal and State agencies, industry, academic institutions, public and private organizations, and individuals. Results of research are made available through publications, symposia, workshops, training sessions, and personal contacts.

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